Move-and-Charge System for Automatic Guided Vehicles

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I. INTRODUCTION

As one of the most prominent technologies, wireless power transfer (WPT) has attracted substantial attention in many applications and is changing the conventional usage of energy in daily life for human being [1]. Generally, the WPT system possesses the advantages of safety, reliability, low maintenance, and electrical isolation [2]. In recent years, automatic guided vehicles (AGVs) are highly demanded with the fast-increasing transportation and logistics market [3]. In order to alleviate the problem of their short driving range, more batteries or frequent charging are inevitable [4]. Rather than increasing the size of batteries or the number of charging ports, the use of WPT for AGVs can greatly facilitate the charging process [5]. Most importantly, because of the absence of metallic contacts, possible electrocution during the charging process can be totally eliminated [6]. Since the AGV usually needs to operate continuously, it is highly desirable to be wirelessly charged during moving. Namely, an array of power transmitters is embedded beneath the workplace while a receiver is mounted at the bottom of the AGV. Another problem for AGV application is that it desires a large number of sensors embedded under the workplace to navigate these AGVs, which will significantly increase the system complexity and hardware cost.

This paper proposes and implements a new move-and-charge (MAC) system for AGVs. Essentially, the proposed rail transmitter not only serves to wirelessly charge the AGV, but also to navigate the AGV based on the variation of mutual inductance. Thus, it can significantly reduce the battery size, while eliminating the risk of electrocution and the guiding sensors embedded under the workplace. The key is to make use of the DC-DC converter to keep the equivalent resistance constant. When the AGV is misaligned with the rail transmitter, the receiver current will be varied so that the steering part of the AGV will perform the correction of direction to maintain the received power. Consequently, both dynamic charging and navigation can be achieved simultaneously.

II. METHODOLOGY

The proposed MAC AGV system is shown in Fig. 1(a), which includes the rail transmitter designed with 180 mm width and the pad receiver. The rail transmitter is embedded just beneath the ground while the pad receiver is mounted at the bottom of the AGV so that the airgap between them is 80 mm. The rail transmitter design involves only a long primary coil supplied by a single power inverter, which takes the definite advantages of lower investment cost and lower installation complexity than the pad transmitter design for feeding multiple AGVs. For the sake of better flexibility, maintainability and scalability, the rail transmitter design usually adopts the sectional arrangement in which it uses one power inverter per section to feed multiple AGVs. Normally, the rail transmitter should be compensated with capacitors as shown in Fig. 1(b), and the system operation frequency is set at 85 kHz according to the SAE J2954 wireless charging standard. Since the wireless power from the transmitter to the receiver is proportional to the surface area where the magnetic flux passes through, the ferrite based pad receiver is adopted to provide magnetic flux guidance, hence minimizing the flux leakage. In order to provide the effect of navigation without relying on guiding sensors, the DC-DC converter is used to regulate the charging voltage and current, aiming to keep the equivalent resistance constant. If the AGV is not aligned with the rail transmitted, there will be a difference between the received current and reference current. This difference will cause the steering part of the AGV to control the AGV in such a way that the alignment can be restored. In order to predefine this reference current, the magnetic field distributions at different situations are calculated by using finite element analysis software JMAG.

A 200 W MAC AGV system has been designed. As shown in Fig. 2(a), when the pad receiver of the AGV is exactly aligned with the rail transmitter, the magnetic flux density at the height of 80 mm is symmetrical without requiring any correction of direction. When the AGV comes across the right corner rail, the magnetic flux density is shown in Fig. 2(b), where the total effective flux passes through the pad receiver is reduced and hence the received current decreases to 5.5 A so that the right correction is needed. As shown in Fig. 2(c), the current drops fast with respect to the misalignment. It can be observed that the received currents when the pad receiver is above the straight rail and corner rail are 6.6 A and 6.0 A, respectively. Thus, the current of 6.0 A can be regarded as the threshold value to conduct the correction of direction. Finally, an experimental prototype has been constructed and tested to verify the feasibility and controllability of the proposed system. More experimental results including the system efficiency will be given in the full paper.

III. CONCLUSION

In this paper, a new MAC system has been proposed and implemented for AGVs, which not only performs wireless charging, but also automatically navigates the AGV without using guiding sensors. By newly adopting the equivalent resistance adjustment circuit and current threshold control method, it can simultaneously provide wireless power and misalignment correction, hence achieving the desired traction. Most importantly, it can significantly reduce the battery size and hence cost of each AGV, while eliminating the risk of electrocution. This work was supported by a grant (Project No. 17204317) from the Hong Kong Research Grants Council, HKSAR, China.

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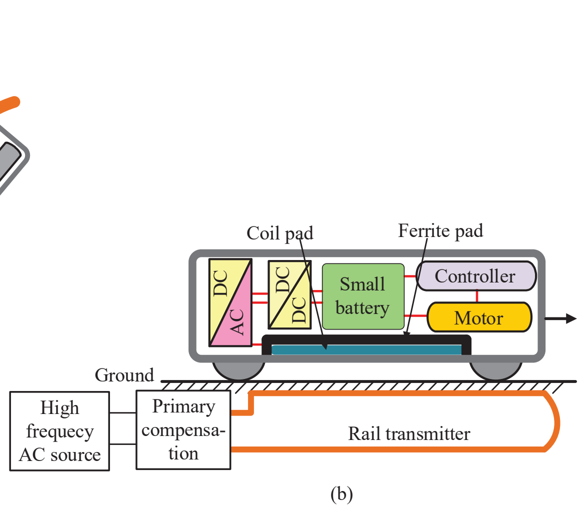

Fig. 1 Proposed MAC AGV system: (a) Schematic. (b) System structure.

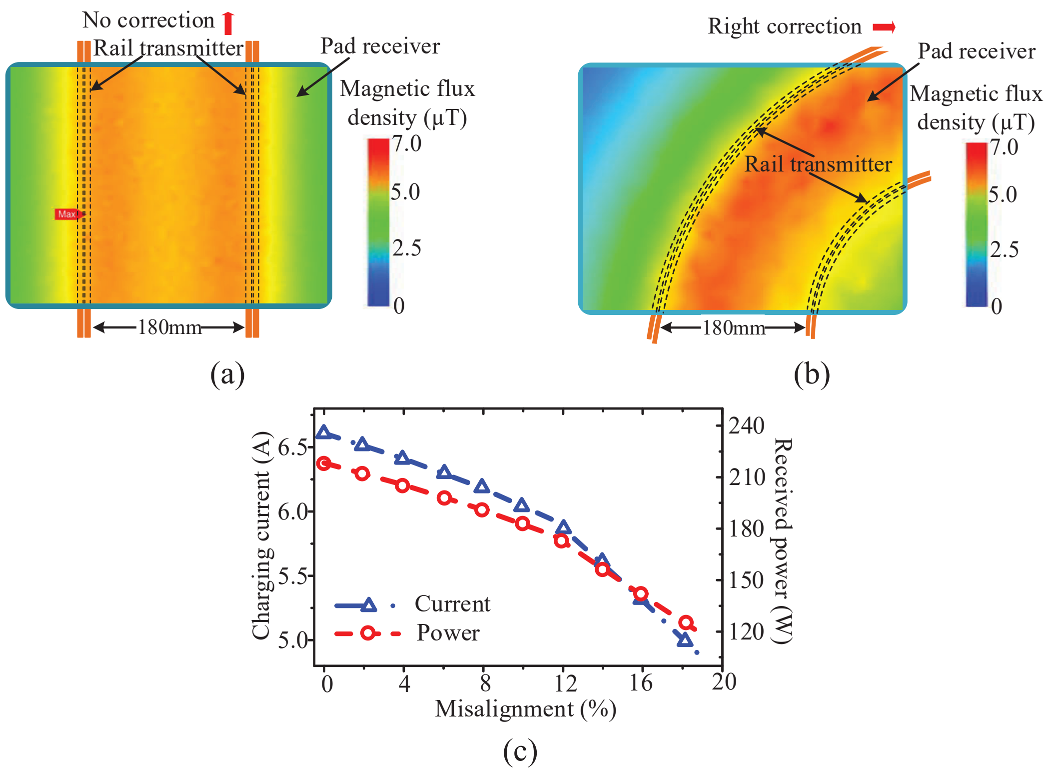

Fig. 2 Simulation results at the height of 80 mm. (a) Magnetic flux density distribution under no correction. (b) Magnetic flux density distribution under right correction. (c). Receiver power and charging current with respect to different misalignments.